INTRODUCTION TO PLATE TECTONICS

Alfred Wegener

12-1 CONTINENTAL DRIFT – AN IDEA BEFORE ITS TIME

Alfred Wegener first proposed his continental drift hypothesis in 1915 when he published “The Origin of Continents and Oceans”

In his **Continental Drift Hypothesis**, a super-continent called Pangaea began breaking apart about 200 million years ago. Continents drifted to their present positions by plowing through the oceanic crust much like icebreakers moving through ice.

Supporting evidence for the hypothesis was

- Fit of the continents
- Fossil evidence
- Rock types and structures
- Climatic Evidence

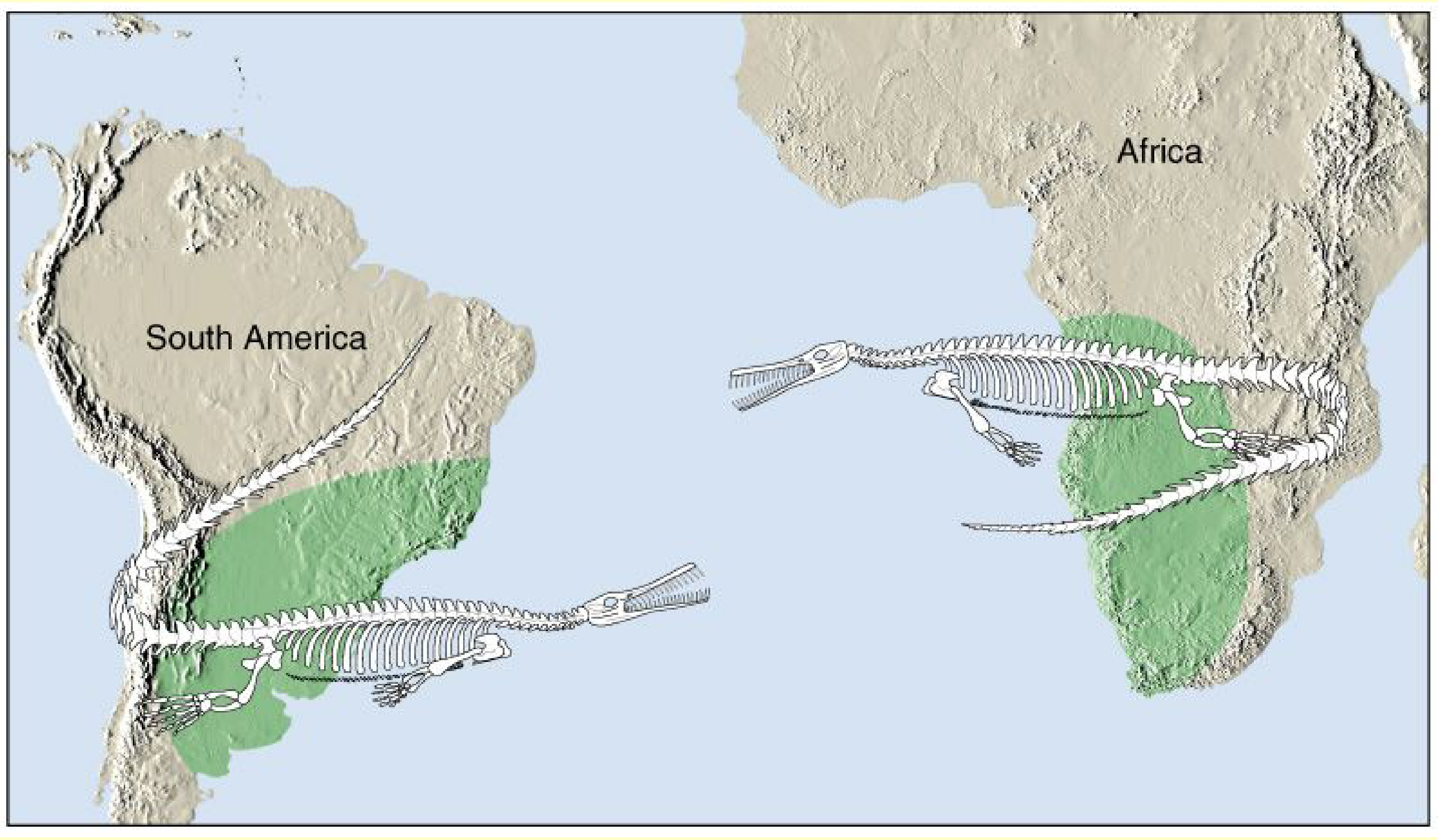
12-2 FIT OF THE CONTINENTS

He noticed that the modern continents fit together quite well along the edges of their continental shelves. (like a jigsaw puzzle)

Pangaea approximately 200 million years ago

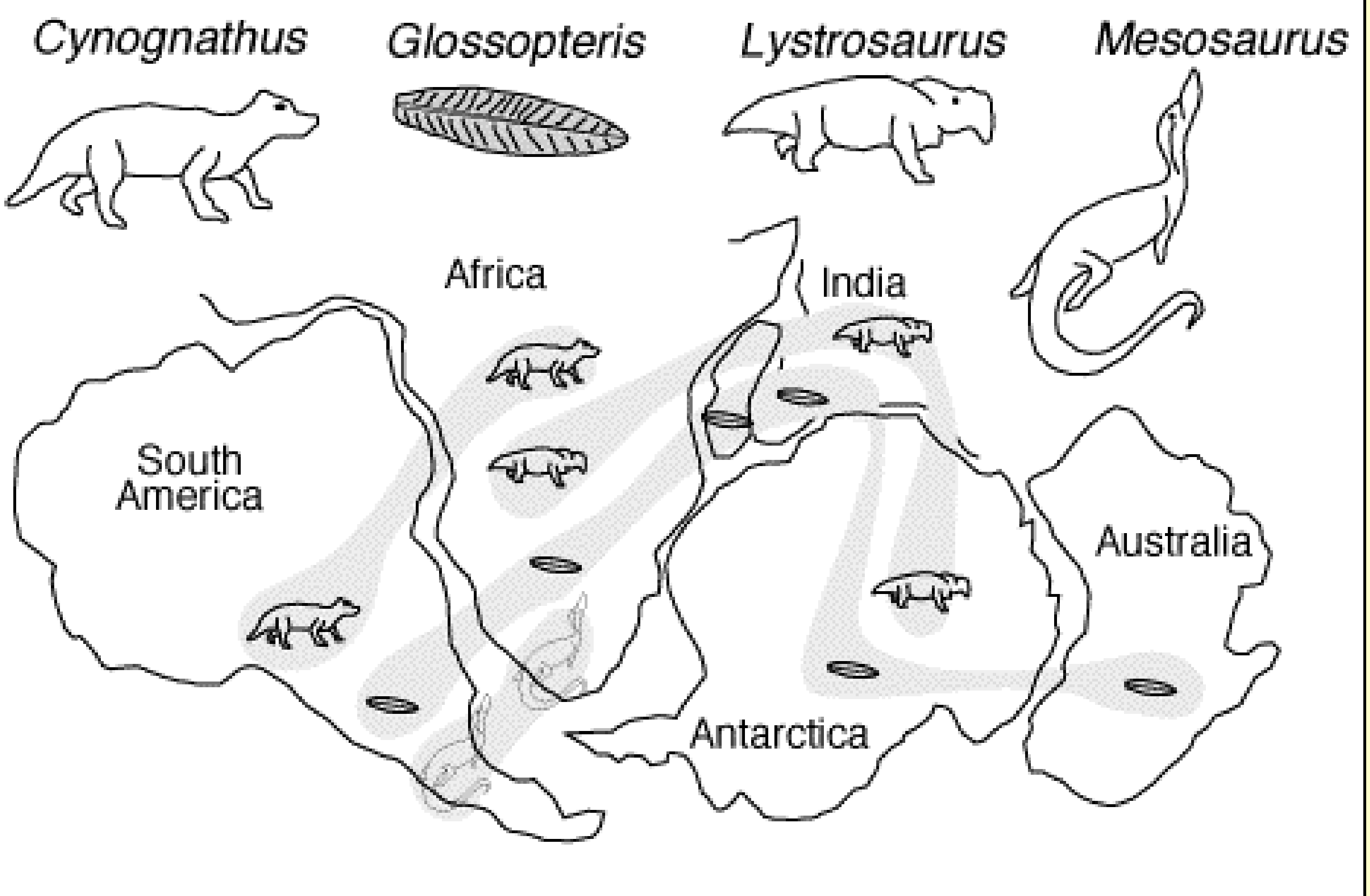
12-3 FOSSIL EVIDENCE

Fossils of the reptlile Mesosaurus are found in Africa and South America. Wegener felt that if this animal was a good enough swimmer to cross the Atlantic then its remains should be widely distributed. They are not.



12-4 FOSSIL EVIDENCE

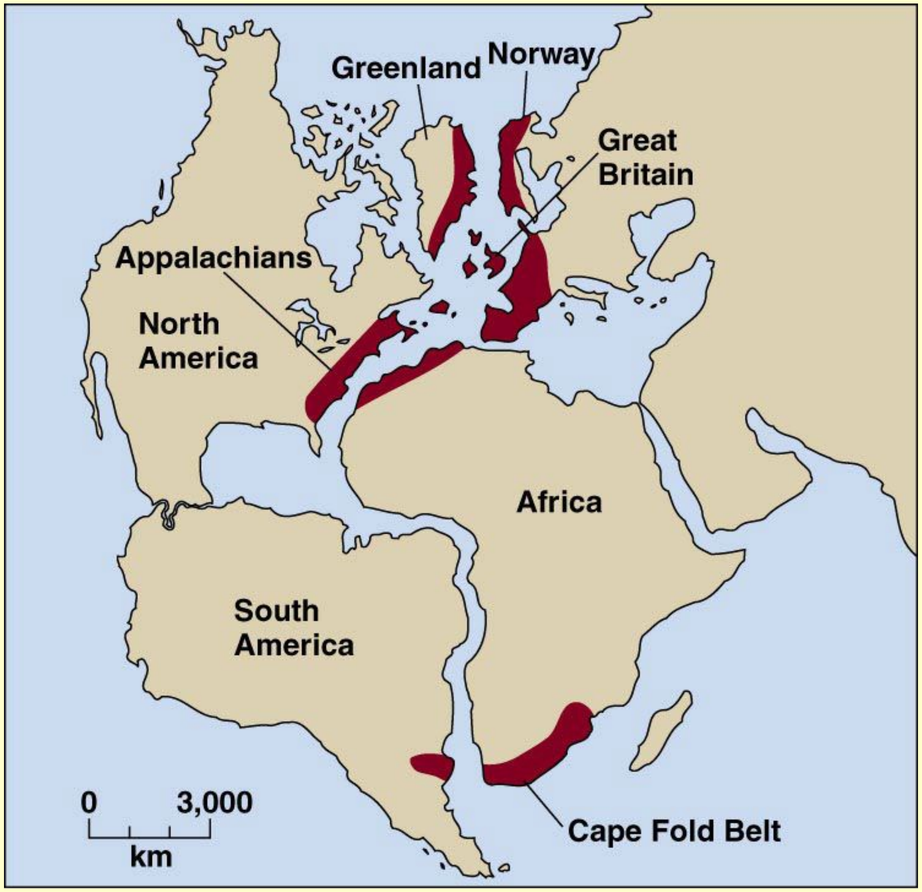
Wegener also used the distribution of other fossils as evidence.



Distribution of fossils across the southern continents of Pangea.

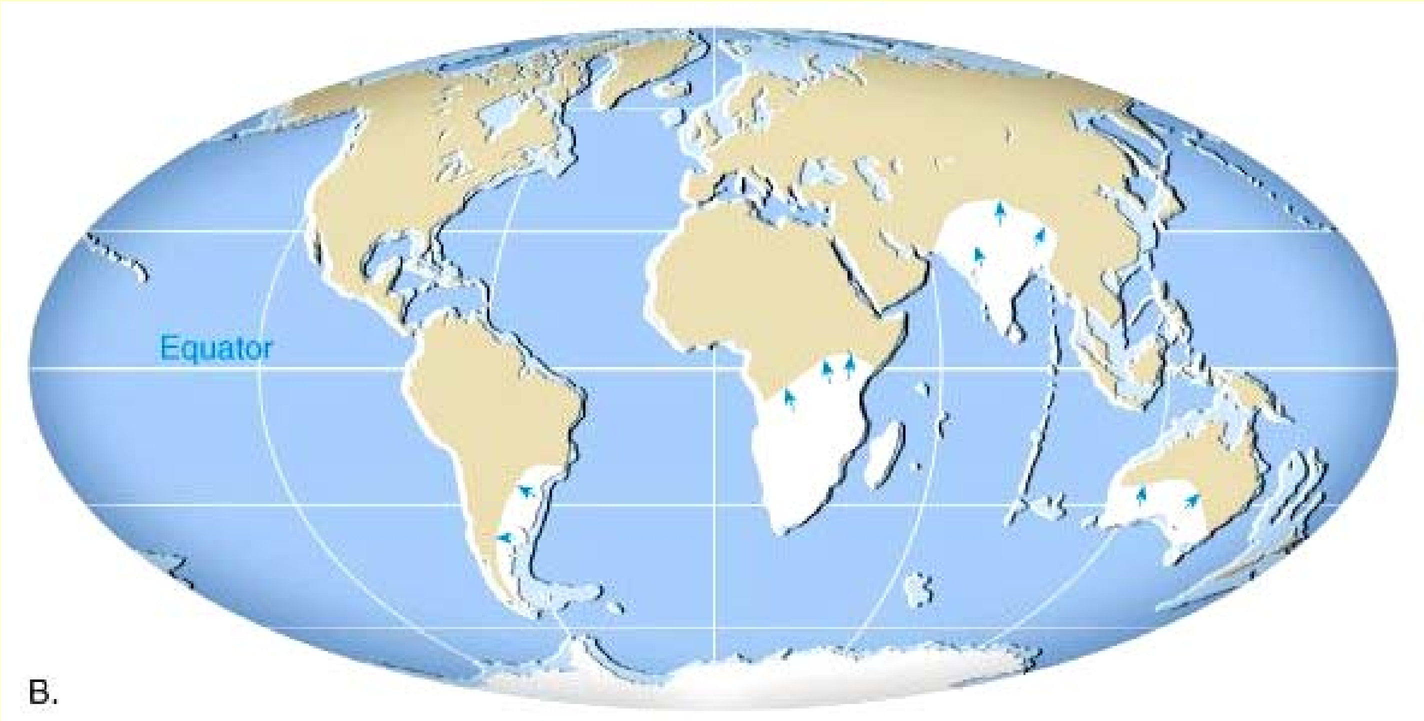
12-5 ROCK TYPES AND STRUCTURES

Mountain ranges with similar age, rock types and structures are found on both sides of the Atlantic Ocean. If the continents are re-assembled as Wegener believed they were 200 Ma, the mountain ranges are continuous,



12-6 PALEOCLIMATIC EVIDENCE

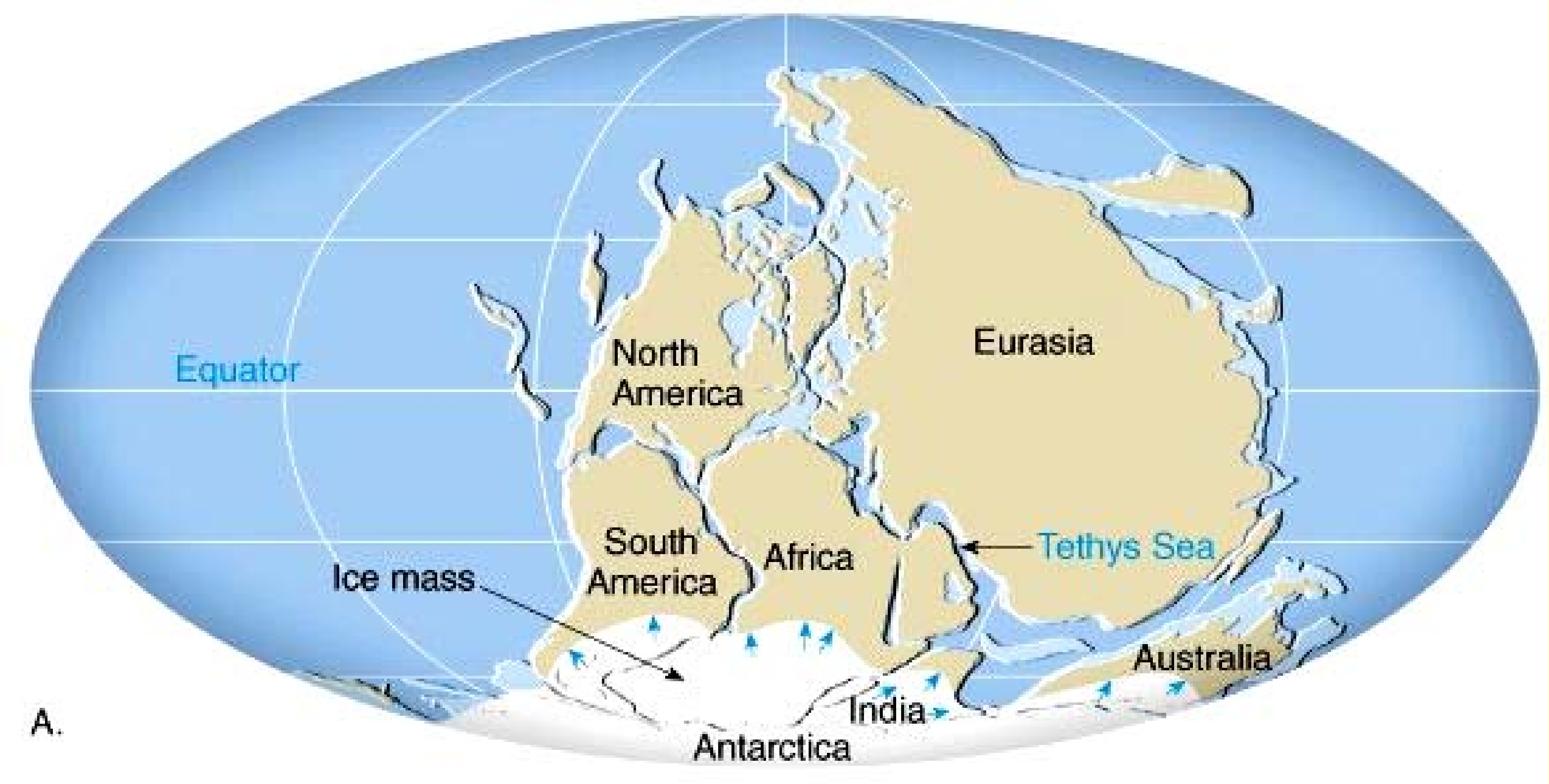
There is ample evidence of ancient glaciation in areas that are now tropical. This suggests continental drift but in addition, the areas covered by these glacial features suggests that the continents were once joined.



Continents as they are today showing areas where evidence of ancient ice sheets exist

12-6b PALEOCLIMATIC EVIDENCE

On the previous slide, direction of glacial movement is shown from sea toward land. This is not how glaciers grow and expand! If the continents are reassembled, the data makes sense.



Pangaea,showing the extent of glacial ice, 300Ma.

12-7 THE GREAT DEBATE

When Wegener published in 1915, his hypothesis was soundly criticized, even ridiculed.

He was correct in principle, but included some incorrect details.

The main objection was the inability of the hypothesis to provide a mechanism capable of moving continents across the globe.

The hypothesis of continental drift was not accepted by the scientific community during Wegener’s lifetime. He died in 1930 but his idea did not die with him.

12-8 THE SCIENTIFIC REVOLUTION BEGINS

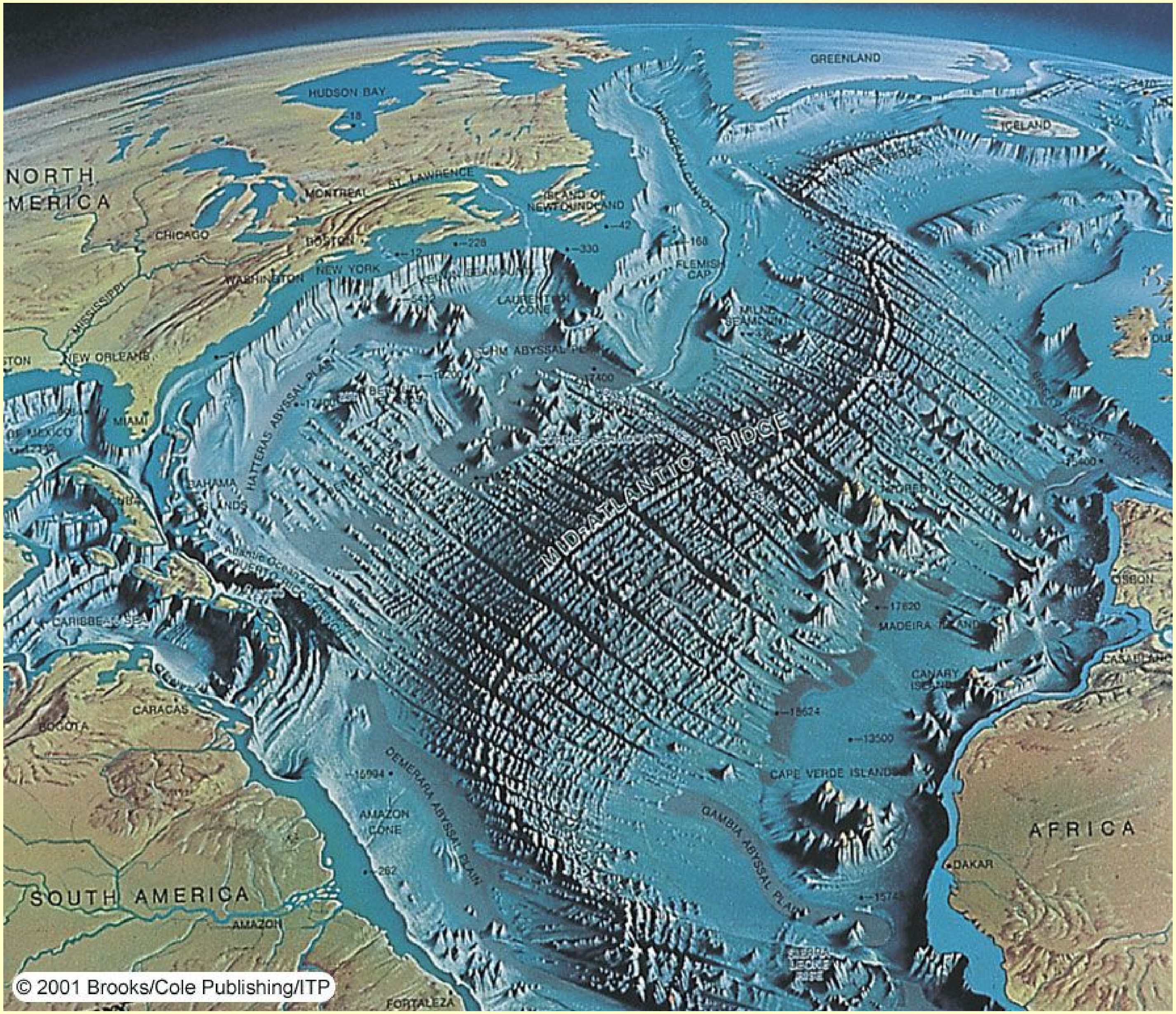
• During the 1950s and 1960s technological strides permitted extensive mapping of the ocean floor.

• Based on echo sounding evidence, H. Hess found the ocean floor to be mountainous with a mid-Atlantic ridge running parallel to the continental margins on both sides of the Atlantic.

• Rocks of the ocean floor were sampled and found to be geologically young (<200Ma), very young at the mid ocean ridge and progressively older away from it.

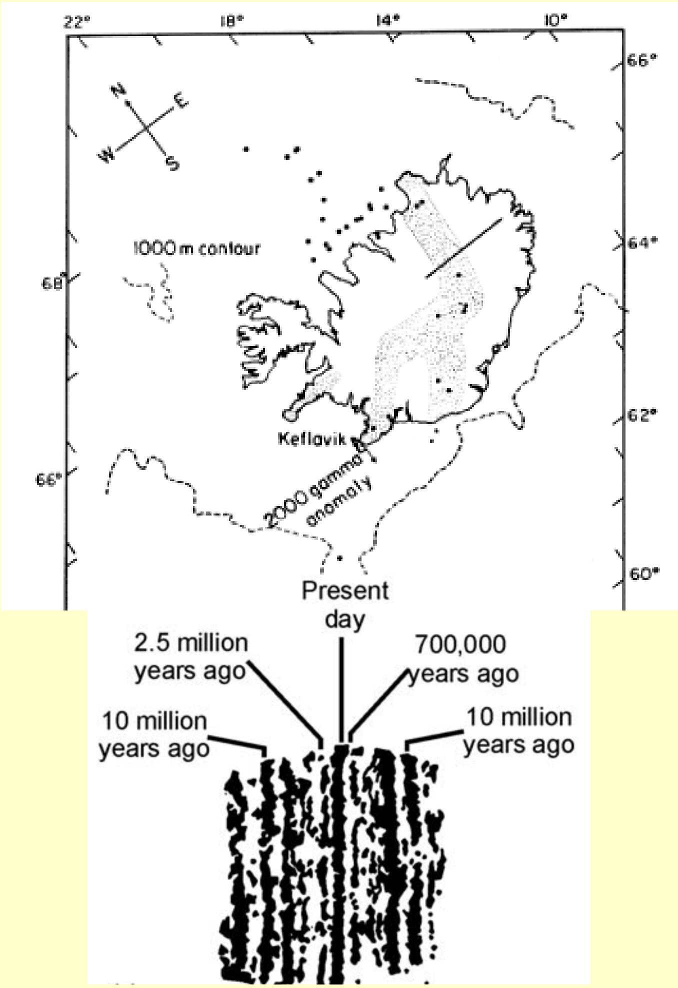
• The **seafloor spreading hypothesis** was proposed by Harry Hess in the early 1960s.

12-9 THE SCIENTIFIC REVOLUTION BEGINS



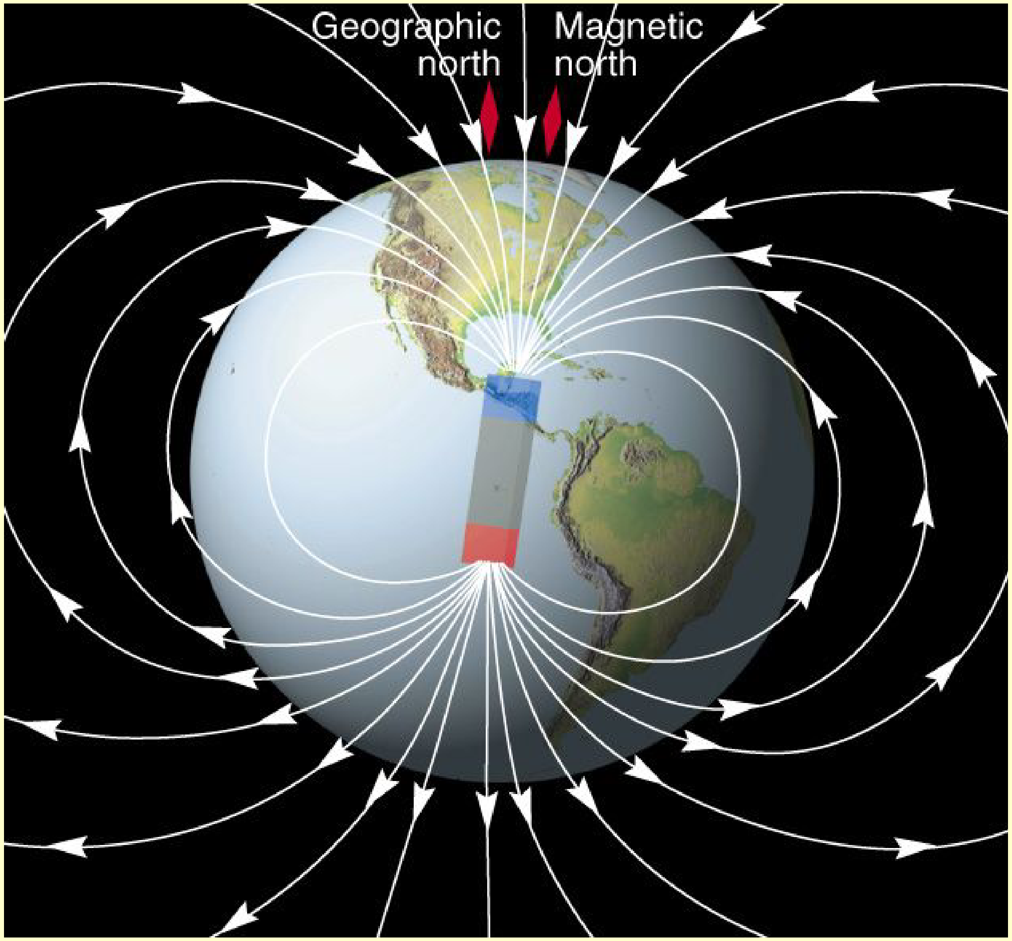
12-10 MAGNETISM

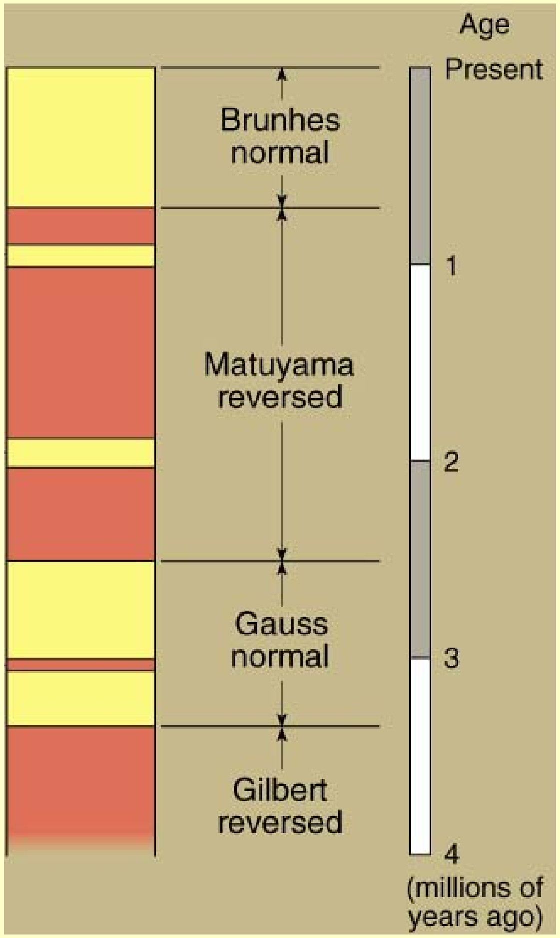
In 1963 Fred Vine and D. Matthews tied the discovery of magnetic stripes in the ocean crust parallel to ridges to Hess's concept of seafloor spreading.



12-11 MAGNETISM

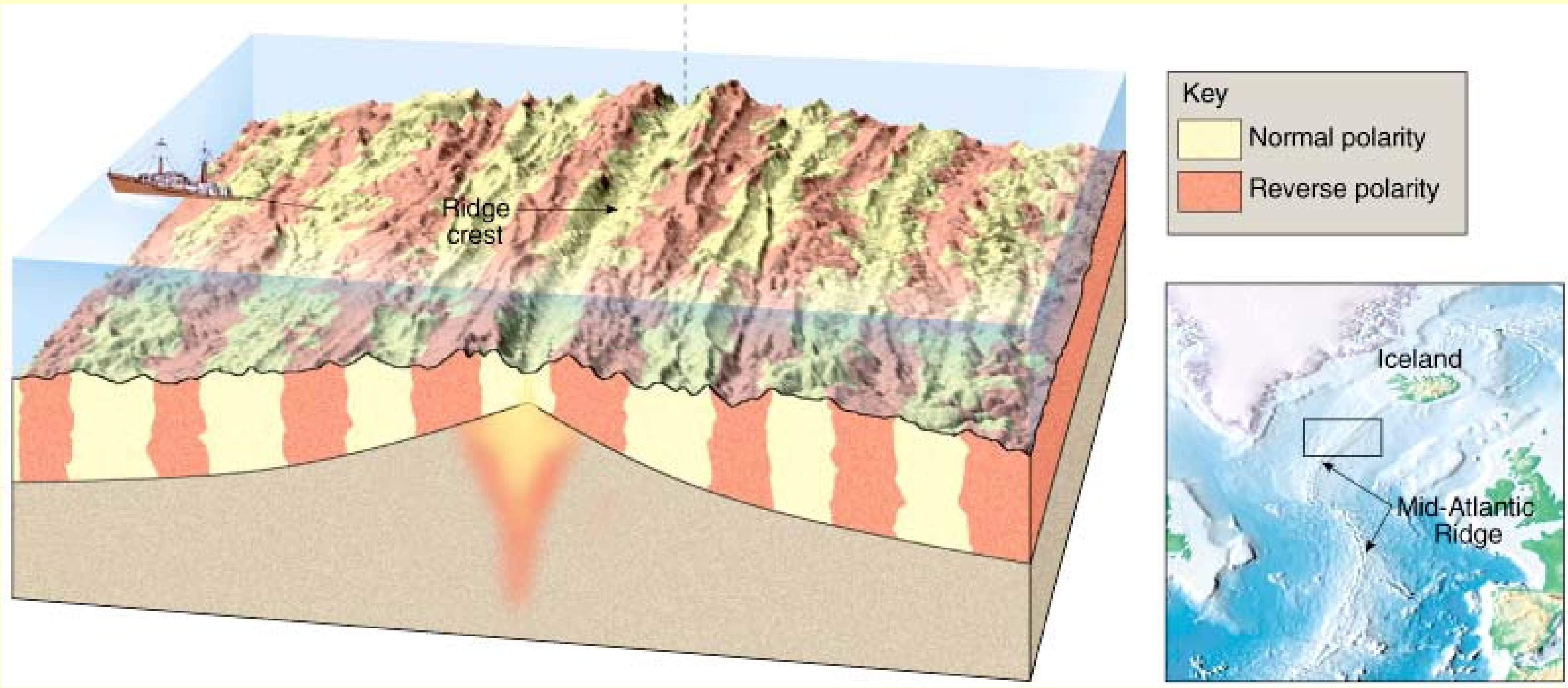
The Earth has a magnetic field. Currently the positive pole is at the north but this has not always been the case. At irregular intervals the Earth's magnetic poles "flip".





12-12 MAGNETISM

The Earth's magnetic field is recorded by the orientation of iron-rich minerals in basalt erupted at the mid ocean ridge



12-13 PLATE TECTONICS

Paleomagnetism (evidence of past magnetism recorded in the rocks) was the most convincing evidence yet to support the concepts of continental drift and seafloor spreading.

Wegener's original hypothesis didn't take into account the importance of the ocean basins but it turns out that they are the key.

The stage is set for the new theory of "PLATE TECTONICS", a much more encompassing theory than continental drift.

It is a composite of ideas that explain the observed motion of Earth's lithosphere through the mechanisms of subduction and seafloor spreading.

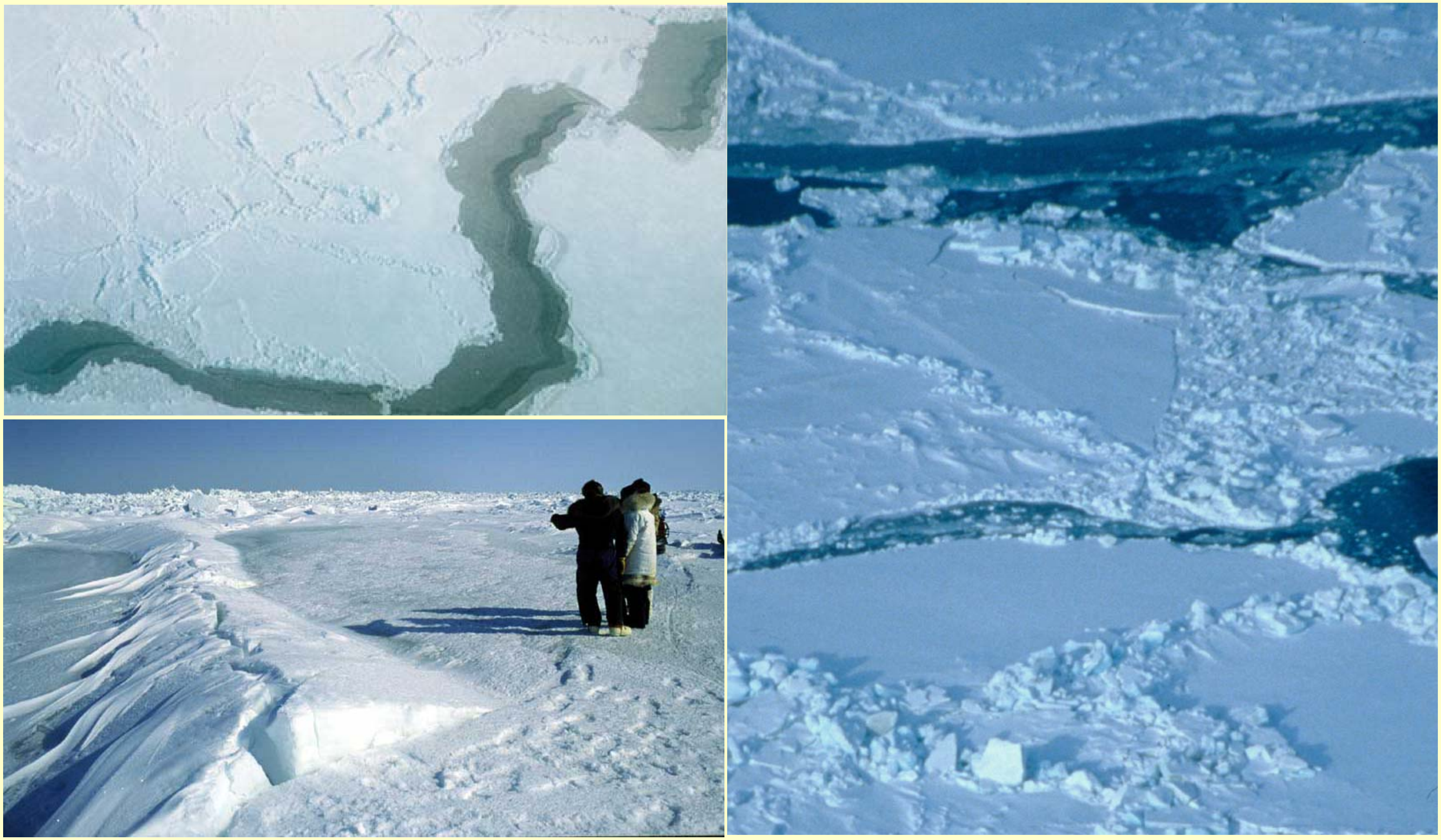
12-14 PLATES

The rigid outer layer of the Earth (the lithosphere) is broken into 7 major plates plus a lot of smaller ones. Several plates include an entire continent plus a large area of seafloor (eg. N.A. Plate)

The lithosphere consists of the uppermost mantle and overlying crust. It sits on top of a weak region in the mantle called the asthenosphere.

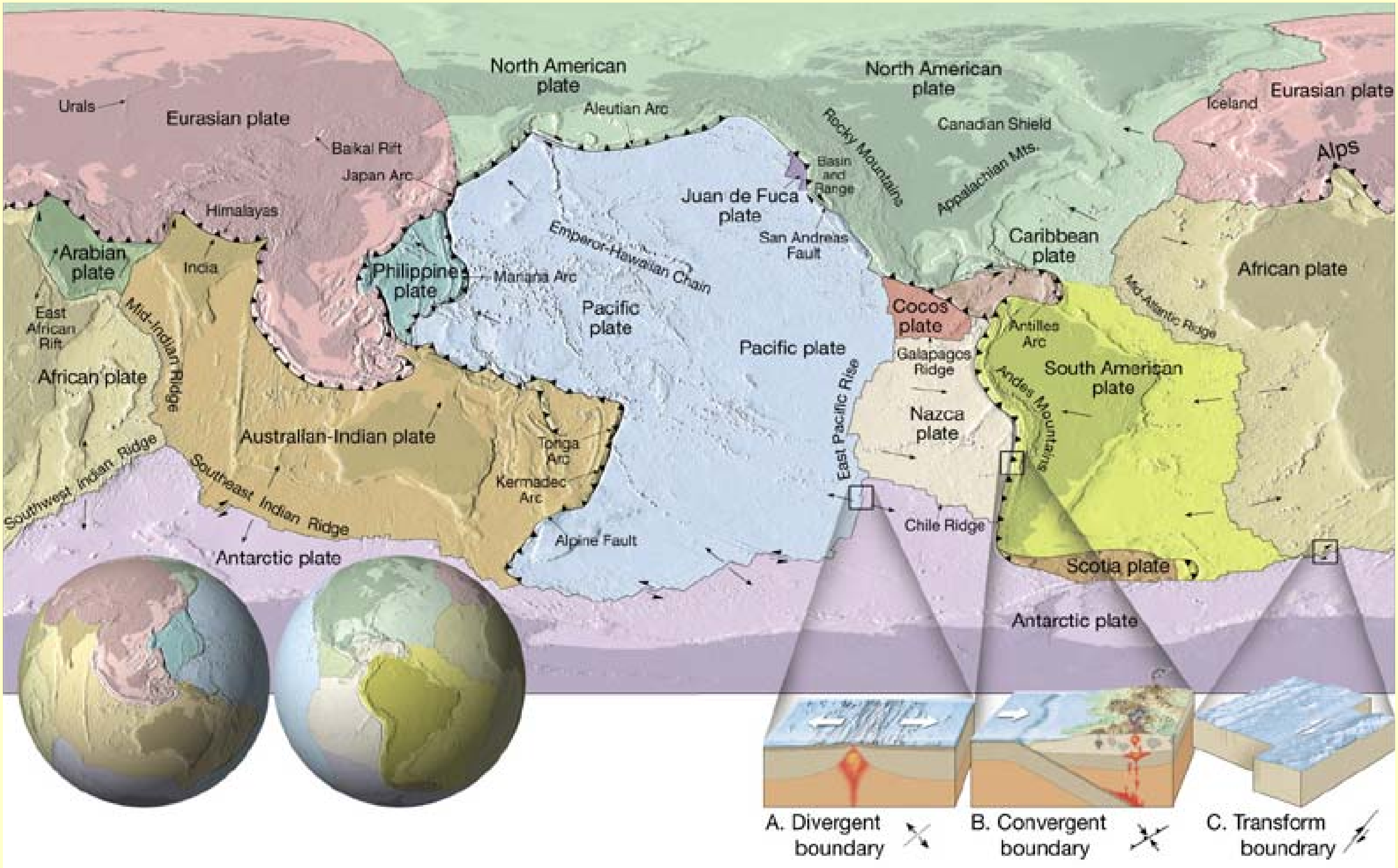
The plates are constantly in motion and continually changing in shape and size.

12-15 PLATES



Lithospheric plates act a bit like sea-ice. They crack apart, join together, buckle upward and get crushed

12-16 PLATES

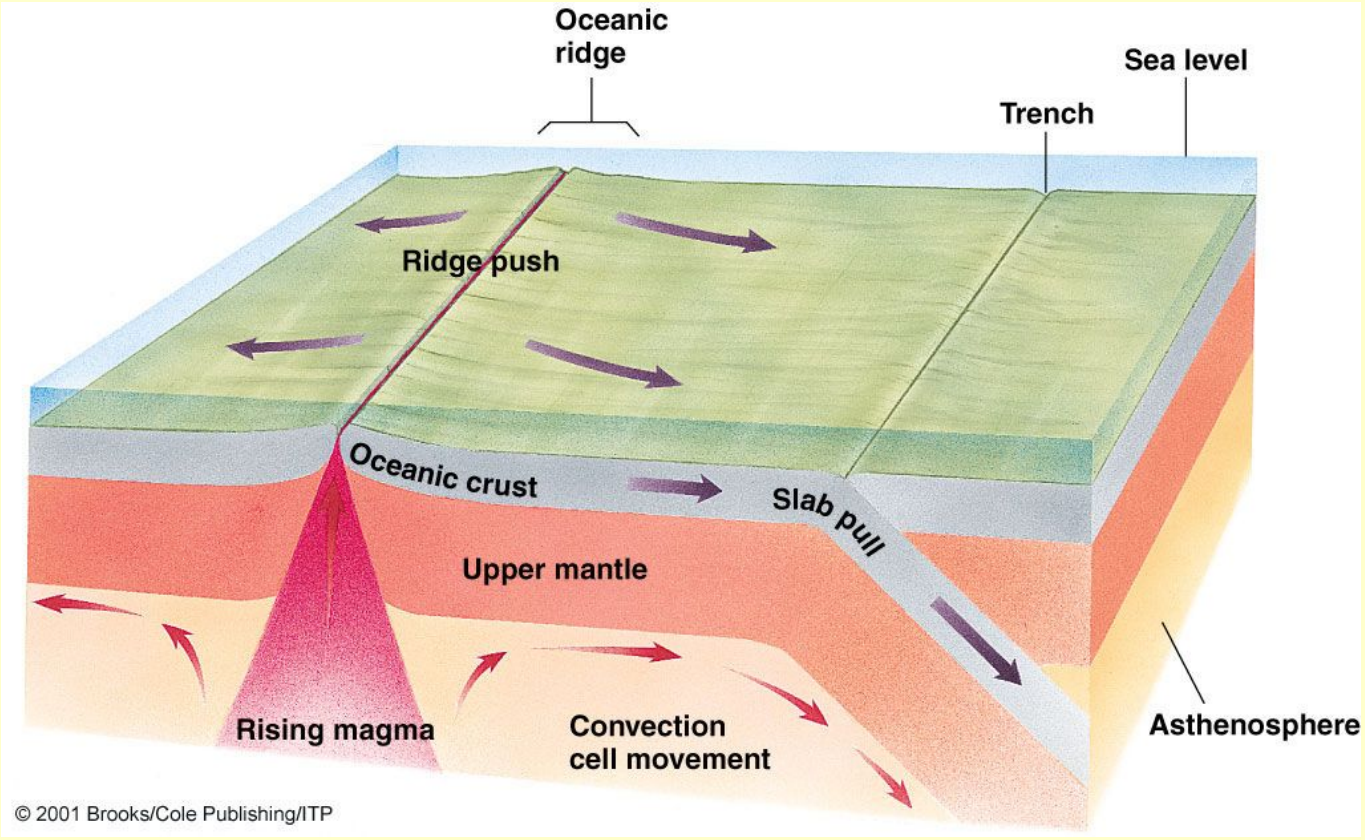


North American plate
North American plate
Urals
Eurasian plate
Aleutian Arc
Baikal Rift
Japan Arc
Canadian Shield
Iceland
Eurasian plate
Alps
Rocky Mountains
Basin and Range
Appalachian Mts.
Juan de Fuca plate
Himalayas
San Andreas Fault
Caribbean plate
Emperor-Hawaiian Chain
Arabian plate
India
Philippine plate
Mariana Arc
African plate
Mid-Atlantic Ridge
East African Rift
Pacific plate
Cocos plate
Antilles Arc
Pacific plate
Galapagos Ridge
South American plate
African plate
Mid-Indian Ridge
East Pacific Rise
Andes Mountains
Nazca plate
Australian-Indian plate
Tonga Arc
Kermadec Arc
Southwest Indian Ridge
Southeast Indian Ridge
Chile Ridge
Alpine Fault
Antarctic plate
Scotia plate
Antarctic plate
A. Divergent boundary
B. Convergent boundary
C. Transform boundary

12-17 PLATES – HOW DO THEY MOVE

Most researchers agree that convective flow in the rocky 2,900 kilometer-thick mantle is the basic driving force.

Related mechanisms are “ridge push” as plates are pushed away from a spreading centre and “slab pull” as plates are pulled along by subduction.



12-18 PLATES

Earth’s plates bump and grind against each other and move relative to each other at a very slow average rate of about 5 centimeters per year. Sometimes the plates lock up and several year’s movement is released all at once in an earthquake.

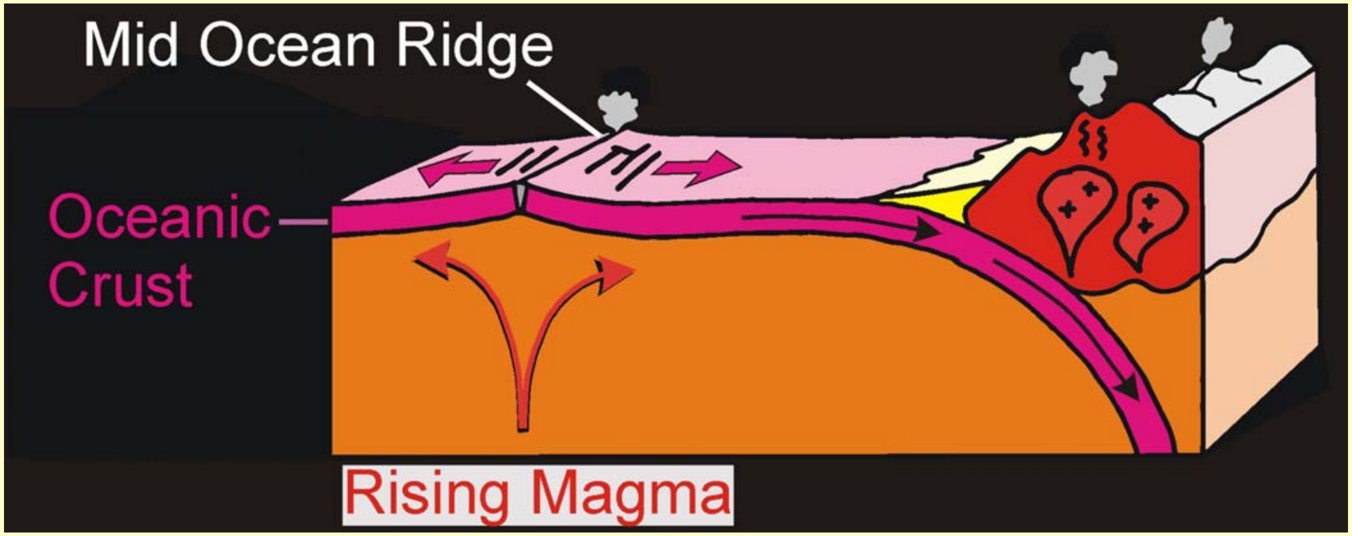
There are three main types of plate boundary.

- Divergent plate boundaries
- Convergent plate boundaries
- Transform fault boundaries

12-19 DIVERGENT BOUNDARIES

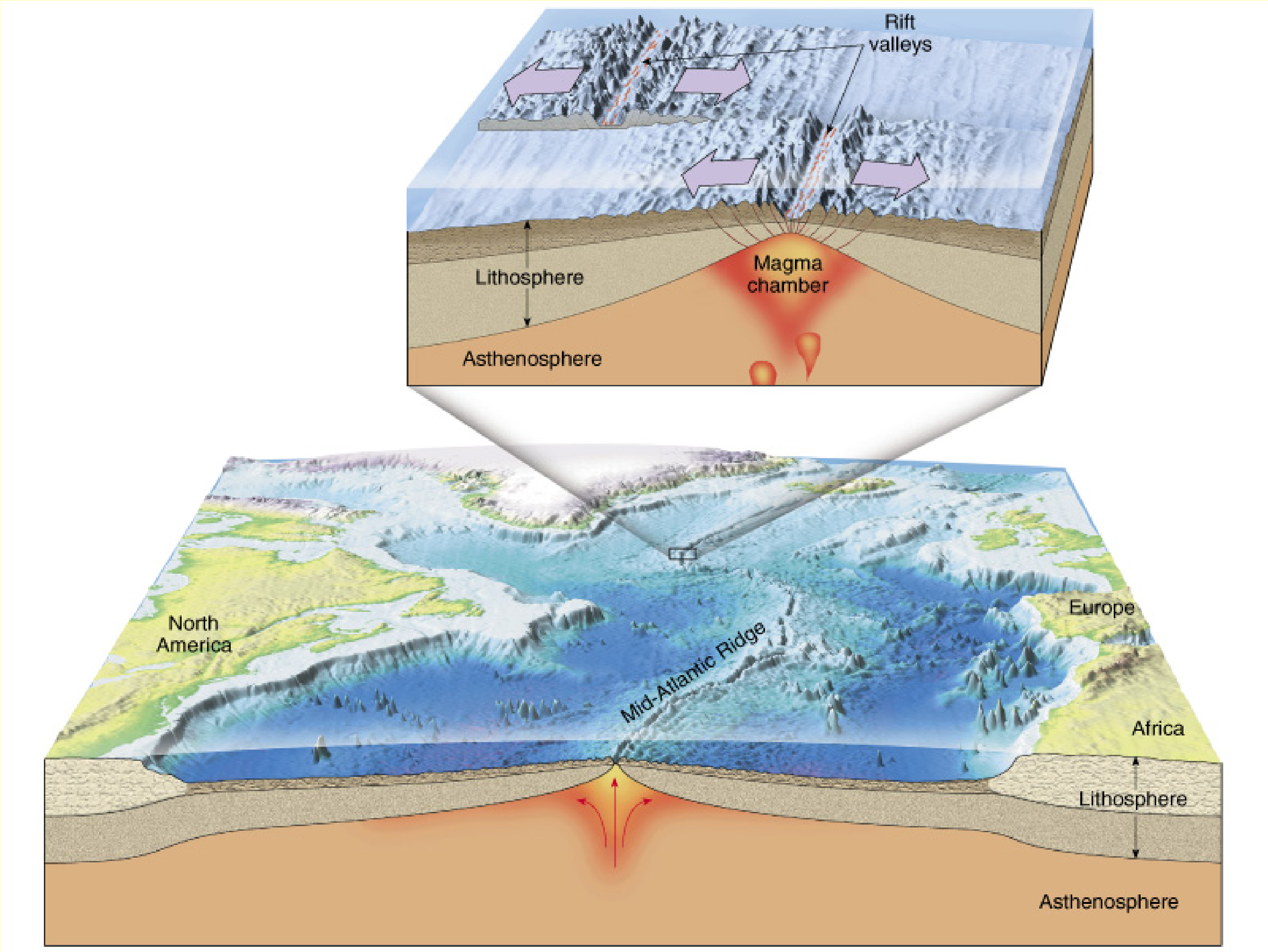
In some parts of the world there is upwelling of hot material from the mantle in what are known as “mantle plumes. This causes the overlying lithosphere to bulge upward and eventually break apart.

Where plates move apart from one another or “diverge”, new lithosphere is formed by the process of volcanism. This most commonly occurs at mid-ocean ridges but can also happen in areas of continental crust.

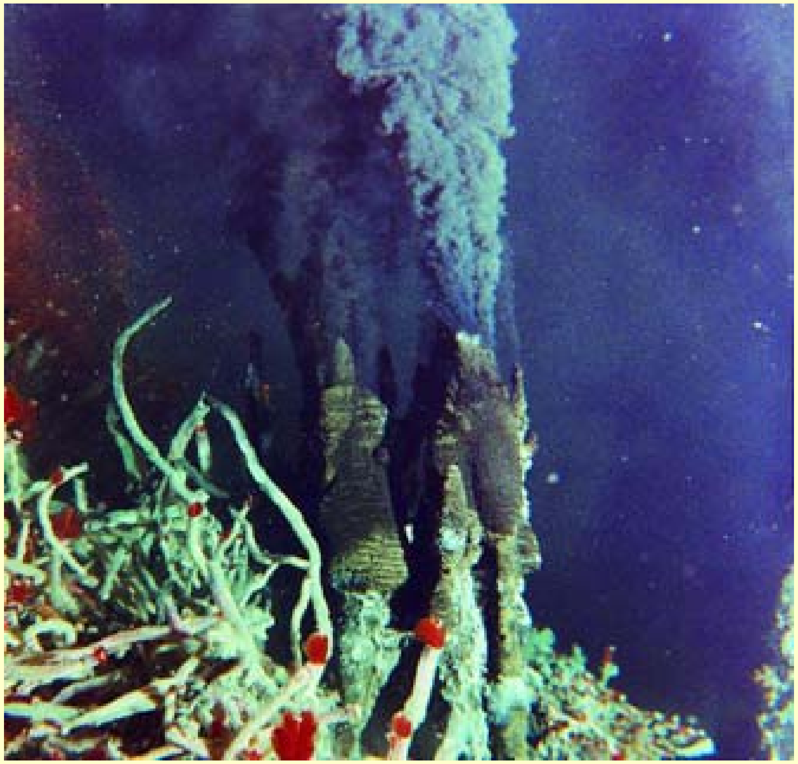


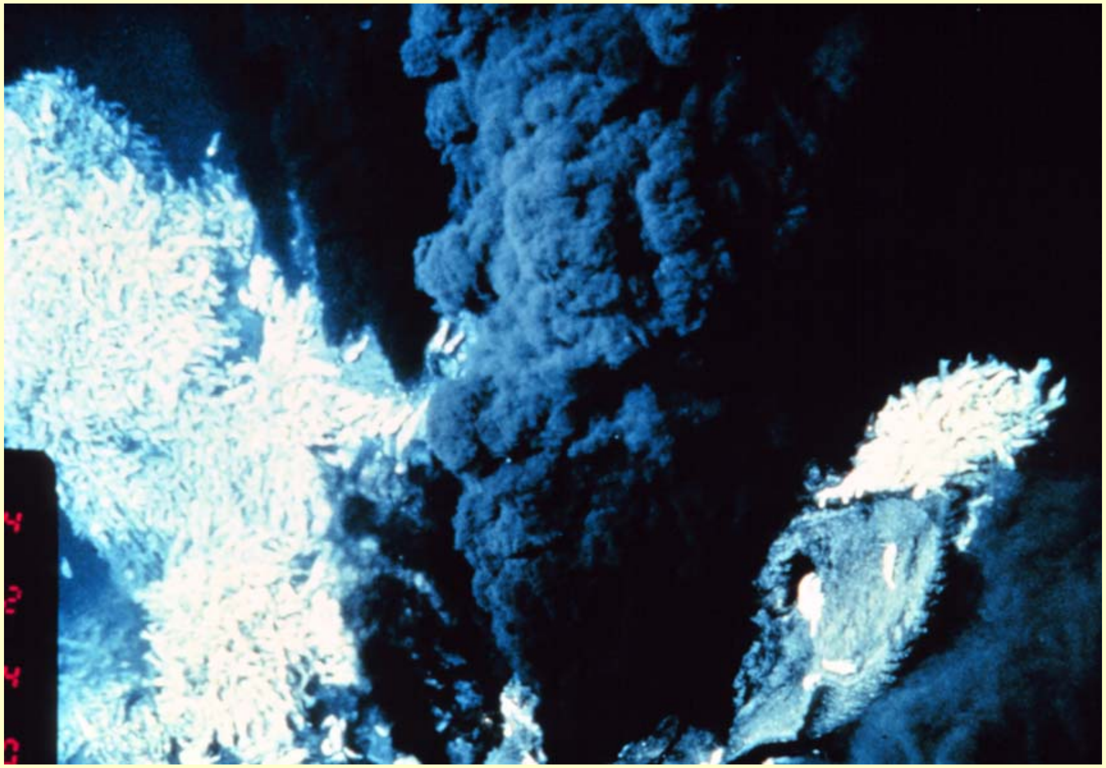
12-20 DIVERGENT BOUNDARIES – OCEANIC

The most common type of divergent plate boundary is a mid-ocean ridge.



12-21 DIVERGENT BOUNDARIES - OCEANIC





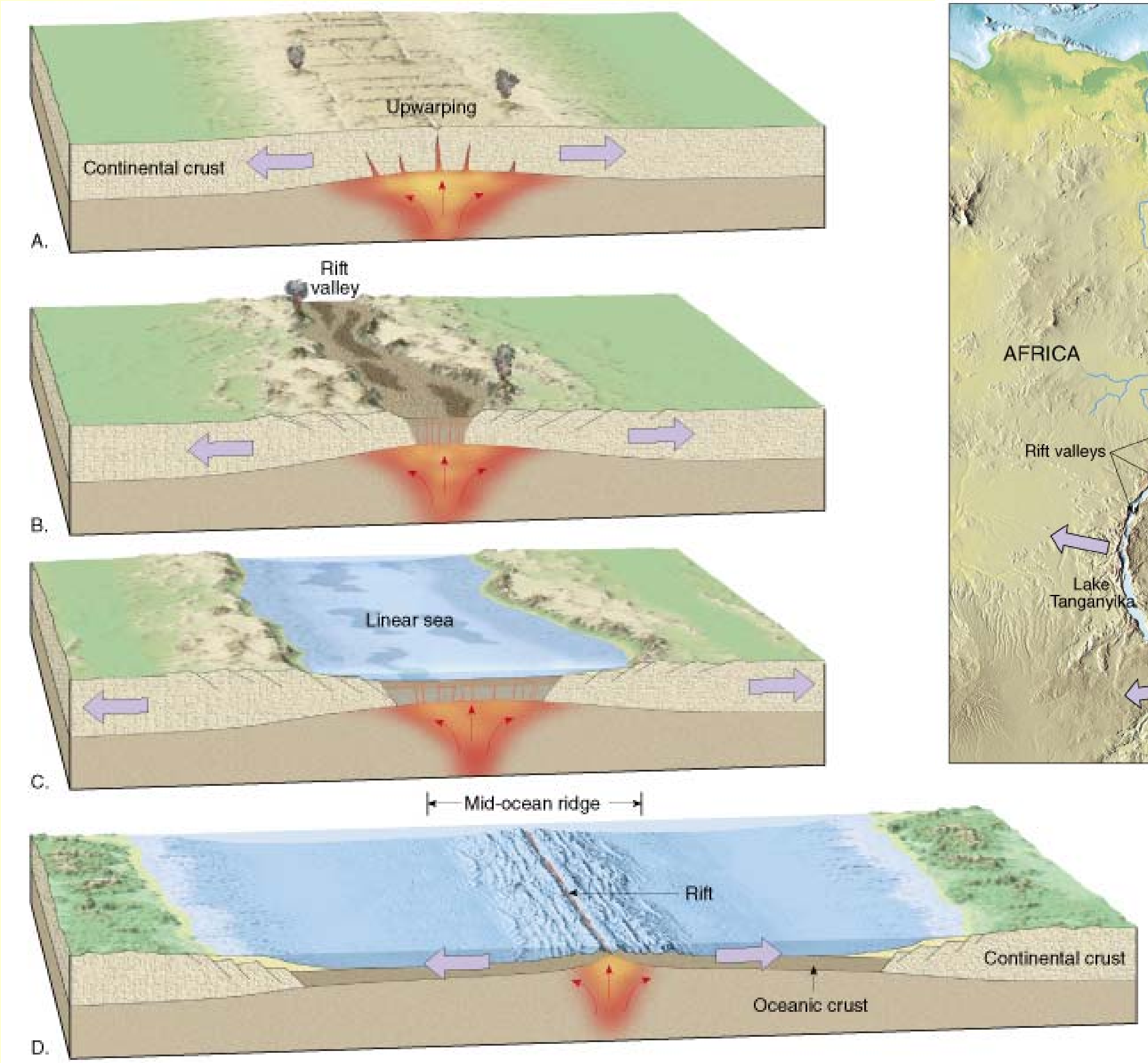
"Black smokers" or hydrothermal vents at the Mid-Atlantic Ridge (2500m depth)

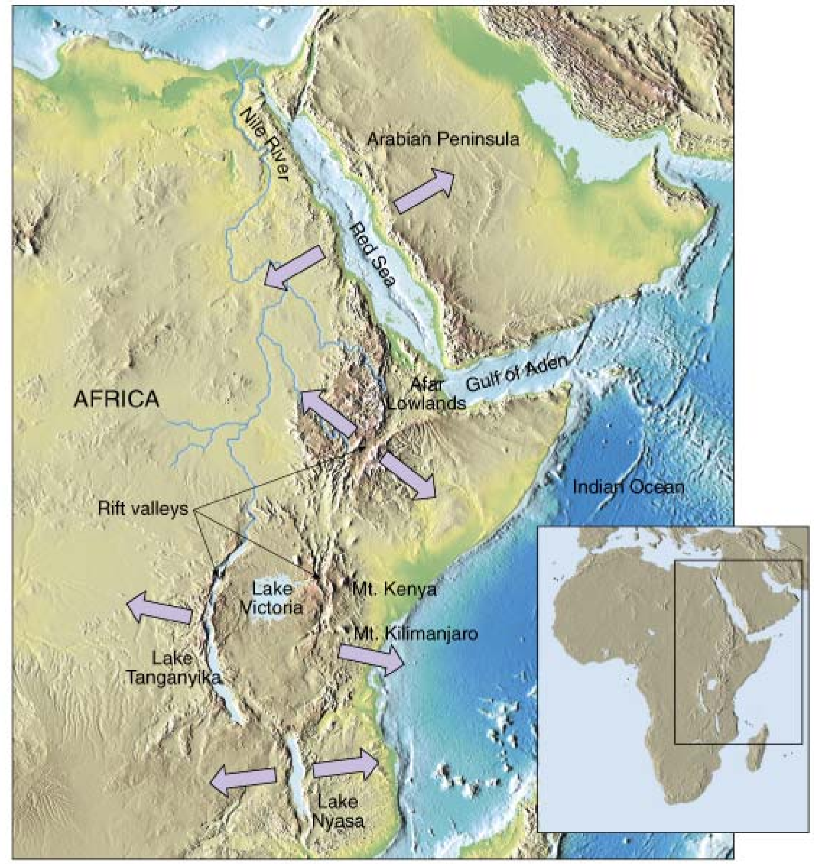
12-22 DIVERGENT BOUNDARIES – CONTINENTAL

Continental rifting splits landmasses into two or more smaller segments.

The best modern example is the East African Rift system.

12-23 DIVERGENT BOUNDARIES - CONTINENTAL

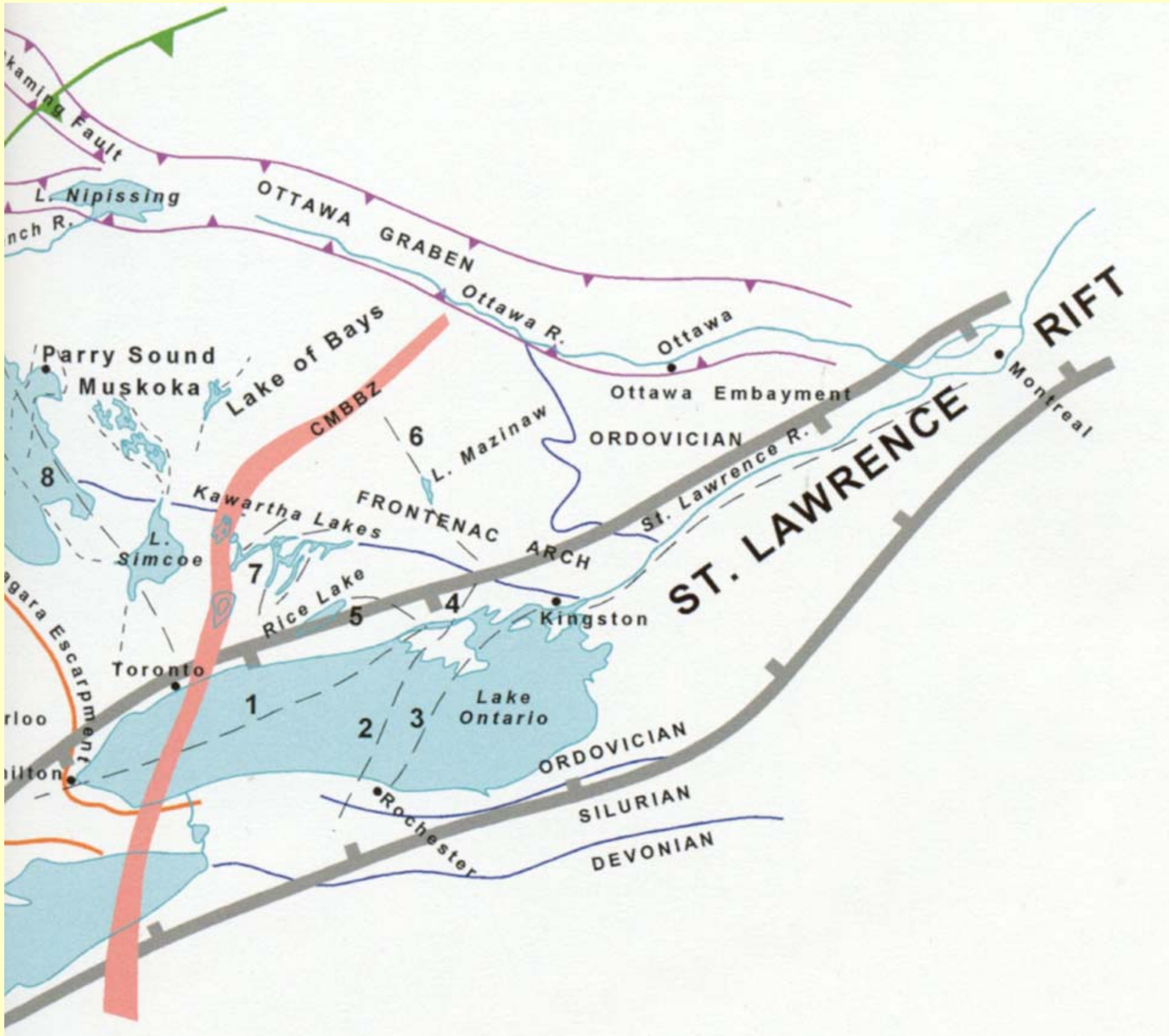




12-24 DIVERGENT BOUNDARIES - CONTINENTAL

Mt. Kilimanjaro, Tanzania

12-25 DIVERGENT BOUNDARIES - CONTINENTAL



Inactive continental rifts in Southern Ontario

12-25b DIVERGENT BOUNDARIES - CONTINENTAL

At the end of glaciation, the ice melted and sea-level rose faster than the land could rebound. This caused the sea to inundate low-lying coastal areas and river valleys, depositing marine clay (quick-clay).

Area once occupied by the Champlain Sea and now underlain by quick-clay.

When subjected to vibration this material liquifies and flows downslope